Considerations in Development of Expert Systems for Real-Time Space Applications*

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Abstract

Over the years demand on space systems have been increased tremendously and this trend will continue for the near future. The enhanced capabilities of space systems, however, can only be met with increased complexity and sophistication of onboard and ground systems, and artificial intelligence and expert system concepts have a significant role in space applications.

Expert systems could facilitate autonomous decision making, improved fault diagnosis and repair, enhanced performance and less reliance on ground support. However, some requirements have to be fulfilled before practical use of flight-worthy expert systems for onboard (and ground) operations.

This paper discusses some of the characteristics and important considerations in design, development, implementation and use of expert systems for real-life space applications. Further, it describes a typical life cycle of expert system development and its usage.

Characteristics: Expert systems for real-time critical space applications need to have the following characteristics:

- Robustness
- Real-time execution (high execution speed compatible with physical requirements)
- Real-world inputs from various subsystems in operation
- Interactive inputs from operators, other expert systems and ground commands
- Extremely high reliability of operation in their application environment
- High degree of correctness and consistency of decisions

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- Testability under various operational modes, failures and credible contingencies
  - Validation and Verification (V&V) and "proof-of-concept"
- Tolerance to failures of hardware, software (knowledge base, inference engine, operating system, etc.), input/output networks and monitoring devices
- Coordination with other expert systems; interaction with a common data/knowledge base
- Fail-safe operations and graceful performance degradation
- Realisability with minimum hardware and power consumption meeting other MIL-STD requirements
- Symbolic and data processing capabilities
- Accomadability to change/modification

Development: Development of expert system should be considered as a system engineering activity encompassing many tasks. The life cycle model of expert system is somewhat different from well-accepted software life cycle, though there are many commonalities. Major phases in life cycle of expert system development include:

- Problem identification/specification
- Acquisition of domain knowledge from experts, previous case history, operation and design documents
- Formulation of knowledge base, knowledge representation
- Choice (and/or development) of suitable inferencing/reasoning schemes and procedures
- Testing of expert system software (residing in development tools) under static (nonreal-time) and real-time environments
  - Review human domain experts and specialists; revisions

- Integration of hardware deliverables and compiled 'expert software'
- Testing under simulated and real-life environments under various operational and failure modes
  - Reviews by human domain experts and specialists; revisions
- Delivery of flight-worthy Expert System; maintenance and upgradation

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